Effect of vegetation and land use on soil fertility in Wutai Mountains of Shanxi Province

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Abstract By comparison of several kinds of forest stands, effect of vegetation and land use on the surface soil was investigated in Wutai Mountains of Shanxi Province. The result shows that larch (*Larix principis-rupprechtii*) and birch stands (*Betula platyphylla*) have more favourable influence on the properties of surface soil than pine (*Pinus tabulaeformis*) plantation and mixed plantation of pine and poplar (*Populus cathayana*). Since deciduous species forest had more annual litter and higher nutrient contents in the litter, thus much more nutrient returned to soil. Mixed planting of pine and poplar could largely improve the soil fertility because litter of poplar is greater in amount and decomposes within 1~2a. The shrub lands contained high nutrient contents in leaves and relatively few human intervention, much of nutrient accumulates in the soil over a long period, resulting in higher nutrient contents in shrub land soil than that in pine plantation soil. Some of them, such as rose (*Rosa bella*), spiraea (*Spiraea trilobata*), ostryopsis (*Ostryopsis davidiana*) and bushclover (*Lespedeza bicolor*) dominant stands, have even higher nutrient status than larch and birch stands. Land-use could significantly change the soil fertility. Soil organic matter and nutrient contents decreased after shrub stand was cultivated as cropland, but increased largely to the pre-cultivated level during following period. It is recommended that larch is the optimum species in the afforestation activities in this area. Natural birch stand should be protected from further damage. Cultivation of shrub land should be stopped. The development and comprehensive utilization of shrub resources should be strengthened by the way of alternative cultivation.
Key words: Vegetation, Soil nutrient, Soil fertility

Introduction

Soil properties depend on climate, vegetation types, parent materials, landform and soil derived age (Beijing Forestry College 1982). Vegetation plays a significant role in the formation of soil particularly for the properties of surface soil. Plants absorb selectively nutrient from soil and build their bodies. The nutrient part of litter decomposed gradually by microbes would return to ground. The root system of plant also plays a significant role in soil properties. Effect of plants on soil depend on the vegetation type, species composition, age, density and structure because each species has different root systems and nutrient content of litter with different decomposition and mineralization on rate (Zhang 1986). In many aspects vegetation may affect soil properties, including physical, chemical, biological properties and etc.. However, this paper concentrated on effect of various stands, shrub and land uses on some soil chemical properties.

Methods

Soil samples within 40 cm (upper layer) on each plot were collected and analyzed. Soil organic matter was determined by means of $K_2Cr_2O_7$, total N by Kjeldahl diffusion method, total P by NaOH fusion -colorimetry, and total K by NaOH fusion-flame photometry (China Criterion Bureau 1987a).

The amount of annual litter of four forest stands is investigated. Since all of shrub is deciduous and most of their litter comes from the leaves, We used roughly the leaf biomass as the annual litterfall. Nutrient contents of all litter or leaf samples were digested with H_2SO_4-$HClO_4$ and determined N by means of Kjeldahl, P by colorimetry and K by flame photometry (China Criterion Bureau 1987b.).

Results and discussion

Description of sites

The investigation was conducted in 1993 in Wutai Mountains of Shanxi Province. Four types of forest stands, such as six shrub lands, a barren grassland, a cropland which was cultivated in 1988 from original Bushclover land and a abandoned cropland which had been given up for about eleven years, were investigated. All the plots were located in the similar site with altitude between 1,280~1,730 m. The mean annual temperature is 6.2~7.2℃ and mean annual precipitation is 566.8 mm. The soil is cinnamon or leached cinnamon derived from granite. The detail

site conditions were described in Table 1.

Table 1. Description of sites

Vegetation types	Altitude / m	Slope direction	Slope (°)	Dominant species	Stockings / hm²	Canopy coverage	Age / a	Average DBH /m	Average Height /cm
Chinese pine	1,630	NE	25	*Pinus tabulaeformis*	2,016	0.75	30	10.6	7.0
Larch plantation	1,680	NE	23	*Larix principis- rupprechtii*	2,500	0.75	15	8.7	7.1
Birch Stand	1,640	NE	26	*Betula platyphylla*	2,067	0.70	30	10.8	6.7
Pine and Cathay	1,640	NE	25	*Pinus tabulaeformis*	1,918	0.70	28	7.1	8.6
Poplar plantation				*Populus cathayana*	1,284		15	9.2	5.6
								Base Diameter /cm	
Rose	1,700	NW	25	*Rosa bella*	1,600	0.60	15	2.2	2.4
Hippophae	1,400	NE	20	*Hippophae rhamnoides*	6,800	0.80	-	-	-
Filbert	1,600	NE	28	*Corylus heterophylla*	5,000	0.60	8	1.2	1.2
Ostryopsis	1,280	NW	35	*Ostryopsis davidiana*	4,100	0.70	10	2.0	1.7
Spiraea	1,440	NE	18	*Spiraea trilobata*	3,460	0.55	-	1.3	0.8
Bushclover	1,610	NE	15	*Lespedeza bicolor*	5,430	0.80	4	0.4	1.3
Barren grassland	1,610	NE	16	-	-	-	-	-	-
Oat land	1,630	NE	20	*Avena nuda*	-	-	-	-	-
Abandoned cropland	1,400	NE	12	-	-	-	-	-	-

Soil fertility of forest stands

Organic matter amount (total N, P and K in the soil of four types of forestland) was listed in Table 2. It suggested that larch plantation and birch stand had the most beneficial influences on soil fertility. Compared to Chinese pine plantation, the organic matter in soil of larch and birch stand was almost tripled, total N increased by 32.9% and 13.3%, total P by 49.7% and 53.9% and total K by 62.1% and 70.9% respectively.

Many factors could contribute to above-mentioned differences, such as root system, amount of litter, properties of litter and site conditions etc. However litter is the most important factor of soil nutrient. Since the sites were similar, the reason for the distinct nutrient content could be found from the annual litter and the decomposition rate of litter as well as nutrient content in the litter. Table 3 shows that not only nutrient content in the litter of larch and birch was higher than that of Chinese pine plantation, but also annual litter was 42.0% and 38.9% more than that of Chinese pine plantation respectively. Pine is evergreen species, while larch and birch are deciduous species with more litter thus more nutrient returned to soil. 64.36 kg/hm² N, 13.13 kg/ hm² P and 25.63 kg/ hm² K annually in larch plantation and 74.98 kg/ hm² N, 6.37 kg/ hm² P and 29.92 kg/ hm² K each year in birch stand returned to the ground, which were substantially greater than those in pine plantation. In addition, litter of larch and birch decomposed much more quickly than that of pine. Field observation showed that birch litter decayed within 2a. It was reported that pine litter took much longer time with the average weight-losing rate of 14%. The quicker the litter decomposed, the more the nutrient returned to soil annually. However, the result above is limited to relatively young plantation with ages between 20~30-year-old. If these forests were allowed to grow enough long time, the result might be different.

Table 2 also showed that mixed planting poplar in the pine plantation could improve soil fertility. The organic matter and total P content in the soil of mixed stand were 72.3% and 43.8% higher than those of pine plantation although the total N and K didn't increase. This might be resulted from the more amount and easier decomposition of litter from poplar (Table 3). It was observed that litter of poplar decayed within 1~2a.

Table 2. Soil (Upper layer 40 cm) chemical properties of forest stands g•kg⁻¹

Vegetation types	Organic matter	Total N	Total P	Total K
Chinese Pine plantation	14.8	1.738	0.386	18.2
Larch plantation	40.4	2.310	0.578	29.5
Birch stand	45.0	1.970	0.594	31.1
Pine and Poplar Plantation	25.5	1.472	0.555	17.4

Table 3. Litter and nutrient return in forest stands

Vegetation types	Annual litter / $t \cdot hm^{-2} \cdot a^{-1}$	Nutrient content in litter / $g \cdot kg^{-1}$			Nutrient returned / $kg \cdot hm^{-2} \cdot a^{-1}$		
		N	P	K	N	P	K
Chinese Pine	2.62	13.5	1.83	6.56	35.37	4.79	17.19
Larch	3.72	17.3	3.53	6.89	64.36	13.13	25.63
Birch	3.64	50.6	1.75	8.22	74.98	6.37	29.92
Pine and Poplar	3.44	15.0	1.96	7.03	51.60	6.74	24.18

Effect of shrub on soil fertility

In general, forest has a larger upper layer and underground biomass, and has a greater influence on soil than other kinds of vegetation. Compared to above-mentioned arbor forestland, soil fertility of shrub land was not poor (Table 4) although their leaf biomass was the main source of litter. But the annual nutrient was much less than that of forest (Table 3 and Table 5). Soil nutrient content of shrub land, such as rose, ostryopsis, spiraea and bushclover could compare with those of larch plantation and birch stand. The fertility of all the shrub land was better than that of pine plantation, mixed pine and poplar plantation. The high fertility of shrub land could be accounted for the high nutrient content in the leaves and relatively little human and stock intervention. And the litter was subject to be damaged by any human or stock disturbance which would cause soil erosion and water run-off and eventually result in the decrease of soil fertility rather than increase gradually.

However, The impact of different shrub was quite different. Table 4 suggested that organic matter was rich in the soil of rose, ostryopsis and spiraea shru lands, and total N was rich in the soil, while relatively poor in hippophae and filvert shrubland. Total P was abundant in hippophae, filbert and bushclover shru lands. Total K was not very plentiful in the soil except that in bushclover shrub lands.

Table 4. Soil (Upper layer 40 cm) chemical properties in shrub lands $g \cdot kg^{-1}$

Vegetation types	Organic matter	Total N	Total P	Total K
Rose	67.3	2.844	0.687	15.20
Hippophae	33.9	1.785	0.739	12.50
Filbert	34.0	1.820	0.736	17.00
Ostryopsis	43.0	2.319	0.450	20.80
Spiraea	41.9	2.371	0.646	17.20
Bushclover	35.5	2.560	0.785	25.66

Table 5. Leaf biomass and nutrient return in shrub lands

Vegetation types	Leaf biomass/ $t \cdot hm^{-2} \cdot a^{-1}$	Nutrient content in Leaf / $g \cdot kg^{-1}$			Nutrient returned / $kg \cdot hm^{-2} \cdot a^{-1}$		
		N	P	K	N	P	K
Rose	0.12	17.8	1.22	6.97	2.14	0.15	0.84
Hippophae	0.23	35.9	2.56	7.49	8.26	0.59	2.18
Filbert	0.18	24.1	1.66	10.95	4.34	0.30	1.97
Ostryopsis	0.31	18.6	1.75	8.13	5.77	0.54	2.52
Spiraea	0.06	19.9	1.35	10.87	1.19	0.08	0.65
Bushclover	0.23	21.2	1.78	0.91	4.88	0.41	0.21

Effect of land use on soil fertility

The main farm crop here is oat. Local farmers usually cultivate cropland from fertile shrub and, abandon after several years' successive cultivation. The crop is totally moved away when ripen and crop stalk is used as fire fuel by local farmers. The oat land in this study was cultivated five years ago from original bushclover shrub land, and the abandoned oat land about eleven years. The four kinds of land in Table 6 located on the same slope with similar site condition, therefore, the bushclover shrub land, oat land and abandoned oat land could represent three successive stages of land use. The nutrient content in the soil was listed in Table 6, which showed that after bushclover shrub land was cultivated to oat land, soil fertility decreased year after year. After five years, total N and total P reduced respectively 40.3%, 57.7%, 12.7% although no significant change in total K. The nutrient level decreased below that of barren grassland which was known as the worst land.

However, when oat land was abandoned, various kinds of grass and shrub immigrated quickly and the soil fertility recovered gradually. After eleven years, soil organic matter and total N were 62.7% and 81.7%

higher than that of oat land. Soil fertility was nearly restored to the level of pre-cultivation. The results indicated that soil fertility could be recovered but it would take much longer time.

Table 6. Soil (Upper layer 40 cm) chemical properties $g \cdot kg^{-1}$

Vegetation types	Organic matter	Total N	Total P	Total K
Barren grassland	24.1	1.300	0.755	22.25
Oat land	21.2	1.084	0.685	25.99
Abandoned cropland	34.5	1.970	0.587	22.58
Bushclover shrub	35.5	2.560	0.785	25.66

Conclusions and suggestion

Larch plantation and birch stand could maintain or improve soil fertility more significantly and more quickly than pine plantation due to litter decomposing easier and relatively having higher nutrient content in litter as well as other beneficial factors. To keep soil fertility, natural birch stand should be protected from further cutting. Larch is the optimum species in local afforestation activities. Pine grew slowly and had little effect on the improvement of soil fertility. Mixed plantation of pine and poplar is also acceptable but poplar requires moist and fertile site condition.

In views of the maintenance and improvement of soil fertility, some shrub stands are even better than arbor stands particularly the pine plantation. Furthermore, shrub stands have similar effect on the soil and water conservation (Zhang 1996a). Shrub was also the main source of local fire fuel, and many species of shrub, such as bushclover, filbert and etc., could be used as materials for knitting basket, fence and artcraft. Beside, the berry fruit of some species of shrub such as rose and hippophae are the sources for drinking. Filbert seed is also a edible cone, and spiraea and bushclover are the oramental species deserving for development (Zhang 1996b). In these points of view, shrub stands in this area should not be regarded as the waste as what the local farmers have thought. There is a great potential to develop and utilize the shrub resource in this area. The traditional cultivation of shrub land to cropland should be stopped immediately so as to avoid soil erosion, water run-off and the decrease of soil fertility.

Soil fertility could be restored during a period time. However, the abandoned cropland should be kept away from stock and human disturbance so that the damaged vegetation and soil fertility could be recovered as quickly as possible.

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